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There are perhaps three horizons, or beds, in which these substances might be expected to occur. The uppermost of these has been removed from the region under consideration, and is the upper Elmdale gas-bearing bed. The next is the one from which the gas occurs at Elmdale, reported to me to be 700 feet below the first. This would be some 600 to 650 feet below the river level. Another might occur at 1,000 or 1,200 feet below the surface. It is also possible that the basal Cherokee shales might prove productive, but this is very doubtful. The Cherokee shales are productive in eastern Kansas and Oklahoma.

I believe this field is worth a thorough test for the existence of these materials. It is too large for one or two wells to test it out thoroughly, unless by accident the first ones happen to hit the most favorable places.

Algæ of Kansas Reservoirs.[1]

JAMES BERNARD MCNAUGHT.

INTRODUCTION.

This report has been prepared with a two-fold purpose. First, it is intended to serve as an aid to the sanitary engineer by explaining the harmful effects of heavy growths of microorganisms in the city water reservoirs, and by describing the organisms causing trouble and the best methods for their eradication. Second, it is the first report of the survey of the algæ of Kansas by the University.

This survey was planned several years ago by Prof. W. C. Stevens and Dr. Grace M. Charles of the Department of Botany and Prof. C. C. Young and Miss Myrtle Greenfield of the Water and Sewage Laboratory of the State Board of Health. As a part of this plan, adapted especially to the need of the sanitary engineer, I began in 1915 to study the algæ of the surface water reservoirs of the cities of Kansas. Through the generosity of Mr. Young, I was provided with reference works and the standard conveniences for collecting the samples over the state, and for making the analyses.

In classifying the 110 species of algæ listed in this report, the following books were found most valuable, "Sylloge Algarum," by De Toni; "Minnesota Algæ, Vol. I," by Miss Tilden; Wolle's "Fresh-Water Algæ of the United States"; "The Green Algæ of North America," by Stokes; "The Algæ of the Fresh Waters of Connecticut," by Conn; "Synopsis des Diatomees de Belgique," by Van Heurick; and "Die Natürlichen Pflanzenfamilien," by Engler and Prantl.

The key adopted in this bulletin is based upon that given by Miss Tilden for the Myxophyceæ, F. S. Collins for the Heterokontæ and Chlorophyceæ, with the exception of the family Desmidiaceæ, where Stokes' classification is used. Shüt was the authority for the Bacillarieæ.

(I take this opportunity of expressing my appreciation for advice and suggestions throughout the progress of the work to Miss Charles and Miss Greenfield.)

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[1] Submitted to the Department of Botany and to the Faculty of the Graduate School of the University of Kansas in partial fulfillment of the requirements for the degree of Master of Arts.

HISTORICAL.

The study of the microörganisms in water has gone hand in hand with the development of the compound microscope, dating back to the seventeenth century. In 1850, Doctor Hassall of London first called attention to the fact that these organisms have a sanitary significance in drinking water. In 1887, the first systematic examination of the water supplies in this country was made by the Massachusetts State Board of Health. This work has been continued up to the present time. During this period surveys of the algæ of the water supplies have been made in several states preliminary to the practical work of the sanitary engineers.

The first data upon the algæ found in Kansas was published in September, 1884, in a bulletin of the Washburn Laboratory of Natural History. This list of twelve species was identified by the Rev. Francis Wolle of Bethlehem, Pa., and was incorporated in the Biological Survey which Francis W. Cragin, professor of natural history, was conducting at Washburn college. In January, 1885, a second list was published containing thirteen new species and additional localities for species reported in the first list. In July, 1886, a third list was published containing five new species and a paragraph on the methods of collecting algæ to be sent in to the laboratory for identification. The final list in January, 1889, was on the Diatomaceæ of the sand from a brook near Arlington, Reno county. Twenty-three species of eleven different genera were listed. In 1911, Prof. B. B. Smyth, curator of the Kansas Museum of Natural History, announced the preparation of a catalogue of the algæ to complete his list of the plants of the state. This plan was left unrealized by his death in 1913. At the University several lists have been prepared which I am compiling for publication as a preliminary survey of the algæ of Kansas. At present the four papers by Wolle, containing the names and localities of fifty-three species of algæ, include all of the work on this subject that has been published for the state of Kansas.

In our neighboring states considerable work on the listing of the local algæ has been published. Nebraska, through its Botanical Survey, has issued several bulletins with lists of algæ prepared by Professors Bessey (1-2-3-25), Pound (1-2-3), Clements (1-2-3) and Webber (24-25). In Iowa, R. E. Buchanan published in 1908, "Notes on the Algæ of Iowa." Colorado has two lists, one on the "Desmida from Alpine Stations," by G. H. Wailes (23), and a "Preliminary List of the Algæ of Colorado," by W. W. Robbins (15). Missouri has a survey bulletin prepared by Miss Ada Hayden (11) on the "Algæ Flora of the Missouri Botanical Garden of St. Louis," containing about one hundred and twenty-five species. The Englemann Botanical Club (9) has prepared a "Preliminary Check List of the Cryptogams and Phanerogams in the Vicinity of St. Louis, Mo.," containing a list of about 135 species of algæ. Oklahoma has published no lists of their algal flora.

RELATION OF ALGÆ TO WATER SUPPLIES.

In Massachusetts the work, including the surveys, carried on for the State Board of Health by Calkins (5), Whipple (26) and others, has shown the marked effect that heavy growths of certain genera of algæ have upon the usability of drinking water. In the first place, the water is often given a very disagreeable odor. For a time this was thought to be due only to the disintegration of the algæ, but was later shown to be caused also by the aromatic oils which are natural to certain species. Some organisms may grow in great abundance without imparting any odor whatsoever to the water, while others, though present in comparatively small quantities, render the water unfit for drinking purposes. Whipple (26) has prepared a table, parts of which are copied below, giving the natural odors of the three large classes of algæ:

TABLE I.

Group.	*Organisms.*	*Natural odors.*
Aromatic odor	Diatomaceæ	Aromatic, geranium, fishy.
Grassy odor	Myxophyceæ	Grassy, moldy, green-corn, nasturtium, sweet.
Fishy odor	Chlorophyceæ	Fishy.

The odors of decomposition are usually more offensive than the natural odors. The Myxophyceæ when decaying give a "pig-pen" odor, Beggiotoa gives the odor of hydrogen sulphide or "rotten eggs," while to some of the other genera the odor of garlic, onions, etc., is ascribed. Water having these strong odors also has a very disagreeable taste. The decaying vegetation often gives the water in addition a yellowish brown color, making it unattractive and in some cases unfit for use even for washing purposes.

Besides this trouble with odors, tastes and color, the algal forms do much damage in clogging the filters and decreasing the length of run quite materially. The diatoms and other unicellular algæ cause the most trouble because of the dense mat which they are able to form over the top of the sand. The filamentous algæ, which grow erect upon the sand, do not thus clog the filter, but on the contrary, they prevent clogging to some extent by their waving threads. However, when these forms decay they, too, settle to the bottom and block the filter. Another danger to the filter is due to the release of gas by these plant forms which at times is sufficient to cause great masses of the mat to rise, thus exposing the sand so that the water filters through it much more rapidly than it should to give efficient results in the tap water.

The elimination of the algæ from the filters can be accomplished by covering them, since these plants can live only in the light. The eradication of the algæ from the reservoirs was a problem, until Moore and Kellerman (14) in 1905 issued a report stating their successful experiments in the removal of algæ by the use of copper sulphate. This treatment has been in practice ever since and has proven to be entirely satisfactory. The method of application as given in the above mentioned paper is as follows: "Place the required number of pounds of copper sulphate in a coarse bag—gunny sack, or some equally loose mesh—and attaching this to the stern of a rowboat near the surface of the water, row slowly back and forth over the reservoir, on each trip keeping the boat within ten to twenty feet of the previous path. In this manner about one hundred pounds of copper sulphate can be distributed in one hour.——"

It is of great importance to determine the exact proportion of copper sulphate to the volume of water to be dosed, since too small a proportion will not affect the algæ, and too great involves unnecessary expense, and may kill off the fish. The quantity of water to be treated in a large impounding reservoir may be estimated by multiplying the number of acres of water surface by the average depth (taken as about one-third of the maximum depth), and dividing this product by three. This gives approximately the number of million gallons of water in the reservoir. (Whipple 26, page 256.)

Since some genera of algæ require more copper sulphate than others (Moore and Kellerman), it is quite essential that the genus of the algæ causing the trouble be determined by microscopical examination. The algæ which appeared in the reservoirs in the two years' survey, and which, therefore, are the most common in Kansas, may be identified by the descriptions in the key and drawings included in this report.

After the quantity of water to be treated and the causitive organisms have been determined, the dosage of copper sulphate may be found by referring to Table II adapted from Whipple (26) and Kellerman (12), page 9.

Immediately following the killing off of the algæ by copper sulphate, the odor often increases for a few days because of disintegration, but this soon passes away. Another effect of the disintegration of the algæ is the perceptible increase in the bacterial count. This can be kept down by the proper use of hypochlorite, which has been used to some extent as an algacide, but has been found to be not as satisfactory as copper sulphate.

When the use of copper sulphate as an eradicator for algæ was first advocated, the question arose as to its effect upon the human system. Ample data is presented in the Moore and Kellerman paper to show that copper salts are used medicinally, and that copper is widely distributed in nature, so that we take it into our bodies in vegetables and other food to such an extent that the amount which we would get in copper treated waters would not be at all toxic.

Aeration also has a marked effect in the decrease of the algæ by liberating the carbon dioxide gas, which is essential to these plants for the manufacture of their food.

TABLE II.

Quantity of copper sulphate required for different organisms.

Organisms.	Parts per million.	Pounds per million gallons of water.
Bacillarieæ.		
Asterionella	0.10	0.8
Fragilaria	0.25	2.1
Melosira	0.30	2.5
Synedra	1.00	8.3
Navicula	0.07	0.6
Flagellata.		
Euglena	1.00	8.3
Dinobryon	0.30	2.5
Myxophyceæ.		
Anabæna	0.09	0.75
Aphanizomenon	0.15	1.2
Clathrocystis	0.10	0.8
Oscillatoria	0.10 to .4	0.8 to 3.3
Chlorophyceæ.		
Cladophora	1.00	8.3
Conferva	0.40 to 2	3.3 to 16
Chlamydomonas	0.50	4.2
Draparnaldia	0.30	2.5
Microspora	0.40	3.3
Scenedesmus	0.30	2.5
Spirogyra	0.05 to .3	0.4 to 2.5
Raphidium	0.30	2.5
Ulothrix	0.20	1.7
Zygnema	0.70	5.8

Then, too, the odors of the algæ are liberated by this treatment. Many of the superintendents of water works of the southern part of Kansas use the aerating system to free the water from the sulphur odor.

S. T. Powell (17) in 1914 reports a ready removal of certain kinds of algæ from drinking water by direct oxidation with ozone, but from a practical point of view this method has never been developed.

Throughout the country much work is being done upon the algæ with special attention to the control of growths in water supplies. With the increasing population will come a larger number of surface water supplies, necessitating more attention on the part of the sanitary engineers to the pollution of the water by algæ.

METHODS.

The cities of Kansas that furnish surface water to the public are compelled by the rules and regulations of the State Board of Health, 1915 (16), to send samples of water collected weekly to be analyzed in the water and sewage laboratory at Lawrence. There are now forty-three such water supplies in the state distributed as appears on the map, plate I. From the reservoirs and basins of the water supplies of these cities the material for this report was obtained. Collections were made in the summer and winter of 1915 and the spring, summer and winter of 1916. This checking of each reservoir five times should bring out any changes due to differences in the seasons and gives us a more complete record on the flora of each reservoir.

The bottles used in collecting the algæ were large-mouthed, glass-stoppered, 100 cubic centimeter bottles, usually filled about one-half full of a two per cent solution of formalin, and bearing the following inscription: "Collect green moss or slime from settling basin. Look carefully near the walls. Do not pour out the liquid in this bottle, but collect slime with a dipper or hand and pour into the bottle." The bottles were placed in the containers with those for the water samples, and were back for analysis within a week after shipment. Most of the analyses were made from preserved material; however, one complete analysis was made from each town on the living material, which was shipped into the laboratory on ice, and allowed to grow in aquaria.

In most cases the algæ were present in sufficient quantities to examine direct from the samples. In those cases in which small masses of the algæ, "moss," could not be found in the basin or reservoir, a liter of water from the basin was taken and the microörganisms present concentrated by the Sedgwick-Rafter filter method (Whipple, 26, page 28). This method of determining the actual number of microörganisms per cubic centimeter of water is especially valuable in recording the reduction of organisms per cubic centimeter during the copper sulphate treatment. By this method it was often difficult to identify accurately the organism under the 16 mm. objective. In order to overcome this difficulty a few drops of the water containing the concentration of organisms was mounted in the usual method under the 4 mm. or higher power. Most of the species found by this method were diatoms and other unicellular algæ.

At times samples of living algæ came into the laboratory in a vegetative condition and the species could not be accurately determined without the fruiting state. This was especially true of the Conjugatæ. For such algæ Kelbs' method was used to induce the fruiting stage (Chamberlain, page 163). According to this method such forms as Spirogyra in a vegetative state were placed in an aquarium of about .2 per cent Knop's solution and left to grow for a few days. When a vigorous growth was shown the algæ were transplanted to a jar of distilled water in the sunlight. In most cases these conditions caused conjugation necessary for classification to species.

In dosing the reservoirs with copper sulphate I have in most cases used the Moore and Kellerman (14) method.

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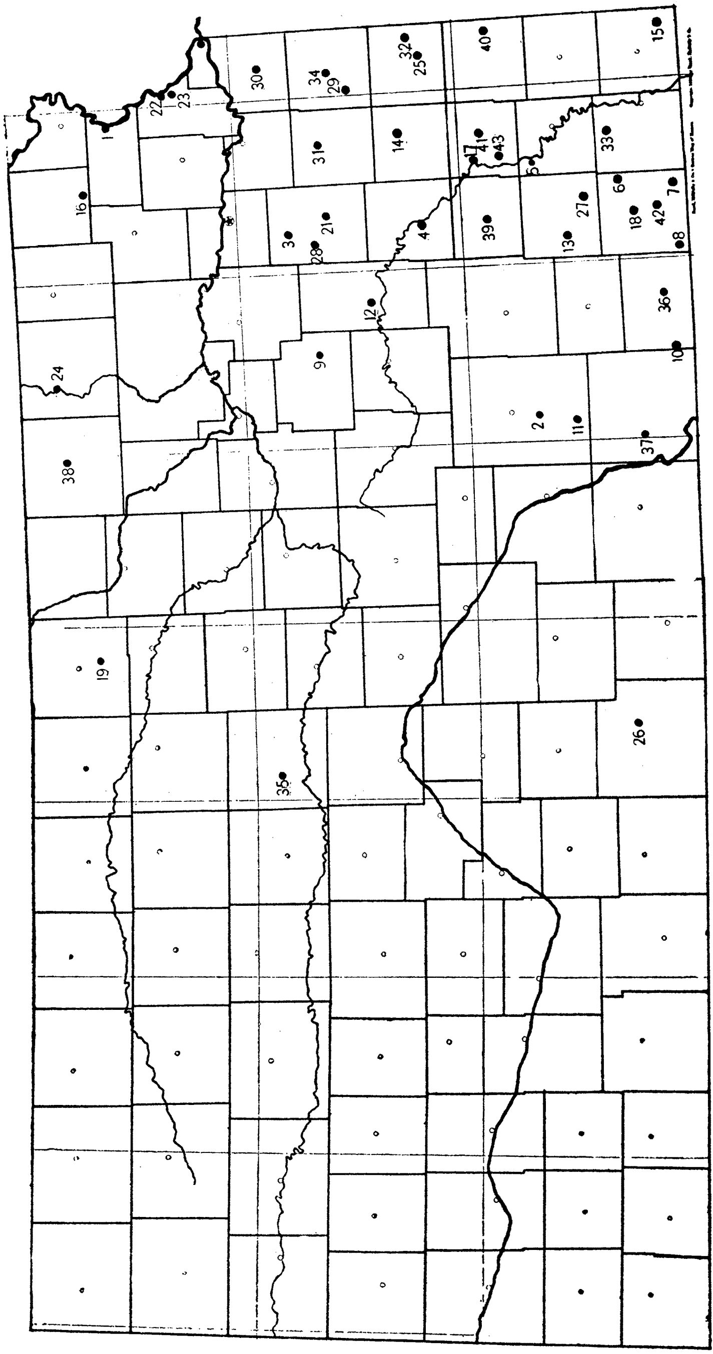

Map of Kansas showing location of stations from which data was obtained.

CITIES HAVING SURFACE WATER SUPPLIES.

1. Atchison.
2. Augusta.
3. Burlingame.
4. Burlington.
5. Chanute.
6. Cherryvale.
7. Coffeyville.
8. Caney.
9. Council Grove.
10. Cedarvale.
11. Douglass.
12. Emporia.
13. Fredonia.
14. Garnett.
15. Galena.
16. Horton.
17. Iola.
18. Independence.
19. Jewell City.
20. Kansas City.
21. Lyndon.
22. Leavenworth.
23. Lansing.
24. Marysville.
25. Mound City.
26. Medicine Lodge.
27. Neodesha.
28. Osage City.
29. Osawatomie.
30. Olathe.
31. Ottawa.
32. Pleasanton.
33. Parsons.
34. Paola.
35. Russell.
36. Sedan.
37. Winfield.
38. Washington.
39. Yates Center.
40. Fort Scott.
41. La Harpe.
42. Dearing.
43. Humboldt.

OBSERVATIONS.

The following key contains the species of algæ which I have found during the period of two years devoted to the collection of data for this report. The list has been prepared in a key form so as to be an aid to those who do not have access to the literature on algæ.

MYXOPHYCEÆ, sometimes called *Cyanophyceæ,* or *Schizophyceæ,* are commonly called the Blue-Green Algæ because of their typically blue-green color. Plants one or many celled, often associated together into families in the form of filaments, spherical or regular gelatinous masses. Some forms endowed with a peculiar motion. Plants found in aerial situations, as endophytes, on rocks, trees, and tanks, especially in fresh, brackish, or salt water, in hot springs and mineral springs.

Key to the Orders of Myxophyceæ.

I. Plants unicellular, single or associated in families or colonies, commonly surrounded by copious gelatinous integument, rarely forming filaments .... *Coccogoneæ.*

II. Plants multicellular, filamentous, filaments simple or branched, generally consisting of one or more cells within a sheath, attached to a substratum or free-floating........................ *Hormogoneæ.*

ORDER I. COCCOGONEÆ.

Key to the Families of Coccogoneæ.

I. Plants epiphytic, often differentiated into basal and apical regions; reproduction by means of nonmotile gonidia..... *Chamæsiphonaceæ.*

II. Plants very rarely epiphytic, not differentiated into basal and apical regions; reproduction by vegetative division of cells in 1, 2, or 3 directions .... *Chroococcaceæ.*

Family I. CHAMÆSIPHONACEÆ.

None of the species belonging to this family have been found in the city water reservoirs.

Family II. CHROOCOCCACEÆ.

Key to the Genera of Chroococcaceæ.

Plants solitary or associated in families or colonies, surrounded by a common gelatinous tegument.

A. Colonies without definite shape, individual sheaths thick, remaining through many divisions, sheath of original mother cell surrounding entire colony; cells spherical enclosed in sheath single or in colonies; cell contents blue-green............1. *Gleocapsa.*

B. Colonies having a definite characteristic shape, free-floating.

  * Cells spherical, having an indefinite arrangement, forming several layers; colonies of variable shape, at first solid, becoming saccate and clathrate.............2. *Clathrocystis.*

  * * Cells spherical having a definite rectangular arrangement, forming a single layer...............3. *Merismopedium.*

1. *Gleocapsa.*

   1. *G. arenaria* (Hassall) Rabenhorst. Plate II, fig. 1.
   Kansas: Paola, July, 1916.
   Iowa (4).

2. *Clathrocystis.*

   2. *C. æruginosa* (Kuetzing) Henfrey.
   Kansas: Emporia, found in large amounts in August and November, 1915; March and August, 1916; Osawatomie, November, 1915; April, 1916; Burlington, April, 1916; Coffeyville, July, 1916.
   Iowa (4); Missouri (11).

3. *Merismopedium.*

Key to Species.

Diameter of cells, 3-6 mic., colonies, 45-150 mic. in diameter ....*M. glaucum.*

Diameter of cells, 1-3.2 mic..............*M. tenuissimum.*

   3. *M. glaucum* (Ehrenberg) *Nägeli.* Plate II, fig. 2.
   Kansas: Garnett, August, 1916; Lyndon, March, 1916; Osawatomie, August and November, 1916; Coffeyville, October, 1916.
   Iowa (4); Nebraska (24); Colorado (15).

   4. *M. tenuissimum* Lemmermann.
   Kansas: Burlingame, October, 1916.
   Colorado (15); Missouri (11).

ORDER II. HORMOGONEÆ.

Key to Families of Hormogoneæ.

I. Filaments frequently branched, containing one or more trichomes; sheaths variable, more or less gelatinous; trichomes consisting of a simple row of cells uniform along their entire length, except for the apical cells which are sometimes attenuated; heterocysts absent; reproduction by vegetative division................*Oscillatoriaceæ.*

II. Sheaths very delicate, often invisible; trichomes usually tortuous and entangled, consisting of a single row of uniform cells, with heterocysts; reproduction by means of vegetative division, hormogones and gonidia ....*Nostocaceæ.*

Family I. OSCILLATORIACEÆ.

Key to Genera.

A. Sheaths not present.
- * Trichomes cylindrical, straight or nearly so, never forming a regular spiral, free, apex of trichome straight or curved. 1. *Oscillatoria.*
- * * Trichomes unicellular, forming a regular, more or less lax spiral .... 2. *Spirulina.*

B. Sheaths present.
- * Filaments simple; sheaths cylindrical, firm; trichomes single within the sheath; apex of trichome straight.
  - *a.* Filaments simple, more or less agglutinated by their mucus sheaths .... 3. *Phormidium.*
  - *b.* Filaments simple, free, free-floating or forming a matted mass .... 4. *Lyngbya.*
- * * Filaments frequently branched; sheaths firm, lamellose, transparent or colored; trichomes several with the sheath.
  - *a.* Sheaths solid, colorless, filaments prostrate, woven into more or less compact membranaceous mass. 5. *Hypheothrix.*
  - *b.* Sheaths mucous, not lamellose, always transparent; trichomes many within the sheath........ 6. *Microcoleus.*

1. *Oscillatoria.*

Key to Species.

I. Apex of trichome constantly straight, finally capitate.
- A. Trichomes tapering, 4-6 mic. in diam.; cells quadrate or shorter, but never very short; plant mass light blue-green... *O. agardhii.*
- B. Trichomes not at all or briefly tapering, 6-8 mic.; often interrupted by inflated refringment cells................ *O. anguina.*

II. Apex straight or curved, not tapering.
- A. Trichomes, 4-10 mic. in diam., slightly constricted at the joints; cells, 2.6-5 mic. in length; transverse walls usually furnished with two rows of granules......................... *O. tenuis.*
- B. Trichomes, 2-3 mic. in diam., not constricted at the joints; cells, 4-8.5 mic. in length, commonly marked with two protoplasmic granules .... *O. amphibia.*
- C. Trichomes, 1-1.5 mic. in diam., often rolled in circinate manner. *O. subtilissima.*
- D. Trichomes, 3.5-4 mic. in diam., not constricted at joints; transverse walls not granulated........................ *O. chlorina.*
- E. Trichomes, .6 mic. in diam., flexible, tangled, not constricted at joints .... *O. angustissima.*

III. Apex of trichome tapering, more or less jointed, hooked or flexuous, not entirely spiraled.
- A. Apical cell capitate.
  1. Trichomes, 2-3 mic. in diam., cells longer than their diameter .... *O. splendida.*
  2. Trichomes, 2.5-5 mic. in diam., cells somewhat quadrate. *O. amoena.*
- B. Apical cell not capitate.
  1. Trichomes, 4-6.5 mic. in diam., here and there interrupted by inflated refringent cells; apex of trichome briefly tapering, hooked or flexuous; cells three times shorter than their diameter. .... *O. brevis.*

2. Trichomes, 4-7 mic. in diam.; apex of trichome obtuse, straight, rarely curved........................*O. cruenta.*
3. Trichomes, 5.5-8 mic. in diam.; slightly constricted at joints; apex of trichomes very gradually tapering, hooked or undulating; cells very long near the apex....*O. cortiana.*

IV. Apex of trichome tapering, not capitate, trichome regularly terebriform, forming a spiral throughout the entire length.

A. Trichomes, 6-8 mic. in diam. ....*O. boryana.*

B. Trichomes, 4-6.5 mic. in diam..................*O. terebriformis.*

5. *O agardhii* Gomont.
Kansas: Masses at Augusta, August, 1915; Fredonia, August, 1915; Winfield, August, 1915; Cherryvale, November, 1915; Masses at Council Grove, April, 1916.
Missouri (11).

6. *O. anguina* Bory.
Kansas: Marysville, October, 1916, mixed with *O. splendida* in mats.

7. *O tenuis* Agardh. Plate II, fig. 3.
Kansas: Burlingame, August, 1915; Ottawa, April, 1916; Pleasanton, August, 1915; Yates Center, August, 1915; Horton, June, 1916.
Nebraska (24); Colorado (15); Missouri (11).

8. *O. amphibia* Agardh.
Kansas: Most common species found. Identified over forty times.
Iowa (4); Nebraska (3); Missouri (11).

9. *O. subtilissima.* Kuetzing.
Kansas: Iola, August, 1915; Parsons, August, 1915, March, 1916; Yates Center, August, 1915.

10. *O. chlorina* Kuetzing.
Kansas: Lyndon, August, 1915, March, 1916.
Nebraska (3).

11. *O. angustissima* W. & G. S. West.
Kansas: Paola, August, 1915.
Iowa (4).

12. *O. splendida* Greville. Plate II, fig. 4.
Kansas: Chanute, August, 1916; Coffeyville, August, 1915, March, October, 1916; Cherryvale, November, 1915, October, 1916, along with *O. terebriformis* forming a mat of deep blue-green on edge of reservoir. Horton, June, October, 1916; Marysville, October, 1916; Osawatomie, October, 1916; Pleasanton, August, 1915; Winfield, August, 1916.
Missouri (11).

13. *O. amœna* Kuetzing.
Kansas: Mound City, March, 1916; Leavenworth, August, 1916; lining reservoir with deep blue-green carpet.

14. *O. brevis* Kuetzing. Plate II, fig. 5.
Kansas: Burlingame, March, August and November, 1915; April, 1916; Coffeyville, July, 1916; Fort Scott, April, 1916; Horton, June, 1916; Independence, August, 1915; March, 1916.

15. *O. cruenta* Grunow.
Kansas: Masses, Leavenworth, August, 1915, November, 1915, August, 1916.

16. *O. cortiana* Meneghini.
Kansas: Chanute, August and November, 1915, April, 1916.

17. *O. boryana* Bory.
Kansas: Much, Emporia, November, 1915.

18. *O. terebriformis* Agardh.
Kansas: Kansas City, August, 1915; Cherryvale, October, 1916; Paola, August and November, 1915; Washington, August, 1915.

2. *Spirulina.*

Key to Species.

I. Trichomes, 1.2-1.7 mic. in diam., forming a loose irregular spiral. *S. major.*

II. Trichomes, 2 mic. in diam., flat, forming continuous band (untwisted, forming a complete ring) with one to four turns........*S. duplex.*

19. *S. major* Kuetzing. Plate II, fig. 6.
Kansas: Atchison, August and November, 1915; Douglass, August, 1915; Coffeyville, October, 1916; Osawatomie, July, 1916, velvety, dark blue-green masses, slimy, mixed with *O. amphibia,* October, 1916; Winfield, August, 1915.
Iowa (4); Nebraska (3); Colorado (15); Missouri (11).

20. *S. duplex* Wolle.
Kansas: Coffeyville, October, 1916.

3. *Phormidium.*

Key to Species.

I. Apex of trichome straight, not capitate, trichomes 3-5 mic. in diam., not constricted at joints, cells 2-4 mic. in length; transverse walls conspicuous....................................*P. papyraceum.*

II. Apex of trichome straight, briefly tapering, capitate trichomes 5.5-11 mic. in diam., not constricted at joints, cells 2-4 mic. in length. *P. subfuscum.*

21. *P. papyraceum* Agardh.
Kansas: Horton, June, 1916.

22. *P. subfuscum* Kuetzing.
Kansas: Iola, December, 1915.

4. *Lyngbya.*

Key to Species.

I. Trichomes not more than 2 mic. in diam.; sheaths thin, colorless, filaments straight or curved.
  A. Filaments 1.9 mic. in diam.; cells 1-1.5 mic. long, contents pale steel color..*L. nana.*
  B. Filaments 1.5-1.8 mic. in diam., cells up to 3.6 mic. long, contents pale blue-green..................................*L. subtilis.*

II. Trichomes 2-6 mic. in diam.; sheaths usually thin, and colorless, but sometimes thick and yellowish.
  A. Sheaths often becoming thick and lamellose; trichomes 2.5-6 mic. in length; filaments coiled......................*L. lutea*
  B. Sheaths thin and colorless; plant mass light green; trichomes 2-3 mic. in diam., not constricted at joints; cells 1-3.7 mic. in length ....*L. digueti.*
  C. Sheaths colorless and firm; plant mass dull blue-green; trichomes 4-6 mic. in diam., not constricted at joints; cells 2.3-3 mic. in length ....*L. æruginee-cærulea*

III. Trichomes 5-25 mic. in diam.

A. Trichomes 8-24 mic. in diam.; apex of trichome slightly tapering, capitate; cells 2.7-5.6 mic. in length; sheaths thickened and yellow with age.................................*L. æstuarii.*

B. Trichomes 6-10 mic. in diam.; apex of trichomes not tapering, not capitate; cells 1.7-3.3 mic. in length; sheaths thickened and roughened with age..........................*L. martensiana*

C. Trichomes 11-16 mic. in diam.; apex of trichomes slightly tapering, somewhat capitate; cells 2-3.4 mic. in length, transverse walls granular; dark blue-green cell contents, sheaths colorless, thick and roughened.............................*L. major.*

D. Trichomes 7.5-13 mic. in diam., constricted at the joints; apex of trichomes not tapering, not capitate; cells 3-10 mic. in length; sheaths colorless, thin, papery....................*L. putealis.*

23. *L. nana* Tilden
Kansas: Masses, Burlington, August, 1915, April, 1916; Council Grove, October, 1916.

24. *L. subtilis* W. West.
Kansas: Ottawa, November, 1915.

25. *L. lutea* Agardh.
Kansas: Iola, August, 1915, December, 1915, March, 1916; masses, Ottawa, November, 1915, October, 1916, dense masses of yellow color; much, Osawatomie, April, 1916, October, 1916; Washington, August, 1916.

26. *L. digueti* Gomont.
Kansas: Coffeyville, November, 1915, July, 1916, masses; Washington, August, 1916.
Missouri (11).

27. L. *ærugineo-cærulea* Kuetzing, Gomont.
Kansas: Council Grove, November, 1915, July, 1916, October, 1916, calcarious deposite; Atchison, October, 1916, slimy velvety growth, carpet; Emporia, March, 1916, August, 1916; Lansing, November, 1915, March, 1916, August, 1916; Paola, March, 1916.
Colorado (15).

28. *L. æstuarii* Mertins Liebman.
Kansas: Coffeyville, August, 1915, November, 1915.
Iowa (4); Nebraska (25).

29. *L. martensiana* Meneghini.
Kansas: Atchison, August, 1915, March, 1916; much, Emporia, November, 1916, August, 1916; Burlington, April, 1916; Coffeyville, July, 1916.
Variety: *Calcarea* Tilden.
Kansas: Lyndon, October, 1916, about edge in calcareous material.

30. *L. major* Meneghini.
Kansas: Neodesha, October, 1916, masses.
Nebraska (3).

31. *L. putealis* Montagne. Plate II, fig. 7.
Kansas: Chanute, August, 1916; Cherryvale, October, 1916, mat about edge of reservoir along with *O. splendida* and *O. terebriformis;* Kansas City, March, 1916; Winfield, August, 1916, March, 1916.

5. *Hypheothrix.*

32. *H. coriacea* Kuetzing.
Filaments long and flexible; plant mass encrusted with calcium carbonate; trichomes 1-1.7 mic. in diam.
Kansas: Leavenworth, April, 1916.

6. Microcoleus.

33. *M. Paludosus* Kuetzing Gomont.
Apical cell not capitate; sheaths somewhat mucous; trichomes 5-7 mic. in diam., not constricted at the joints.
Kansas: Paola, November, 1915, August, 1915.

Family II. NOSTOCACEÆ.

Key to Genera.

A. Trichomes flexuous and contorted; within a definite gelatinous investment ....1. *Nostoc.*
B. Trichomes more or less straight, free or forming a thin mucous stratum; heterocysts and spores intercalary......2. *Anabæna.*

1. *Nostoc.*

34. *N. punctiforme* Kuetzing Hariot.
Plants microscopic, granular, aggregated; filaments closely entangled; trichomes scarcely distinct.
Kansas: Lyndon, November, 1915; Horton, June, 1916.

2. *Anabæna.*

Key to Species.

I. Gonidia oval or spherical, removed from heterocysts in catenate series; trichomes 4-6 mic. in diam.; heterocysts 6 mic. in diam.; 8 mic. in length; gonidia 7-9 by 8-14 mic..............*A. variabilis.*
II. Gonidia cylindrical, curved, variously disposed, trichomes 4-8 mic. in diam.; gonidia 7-13 mic. in diam. and 20-50 mic. in length. *A. flos-aquæ.*

35. *A. variabilis* Kuetzing. Plate II. fig. 9.
Kansas: Horton, August, 1916, great masses along with *A. flos-aquæ,* causing serious trouble by discolorations, bad taste and odor of water.

36. *A flos-aquæ.* Breb. Plate II. fig. 10.
Most common form.
Kansas: Horton, August, 1916; Paola, July, 1916; Coffeyville, March, 1916.
Colorado (15); Iowa (4); Neb. (24); Mo. (11).

CLASS II.

FLAGELLATA is an order of the class Mastigophora of the Protozoa. Cells nucleated with definite external layer of protoplasm provided with one or more vibratile long whip-like flagella; food commonly ingested through the oral aperture; some genera contain chlorophyll and are sustained by nutritional processes resembling those of plants; protoplasm of the cell contains chromatophores, pigment spots, oil globules, etc.

Key to the Sub-Orders of Flagellata.

I. Mostly small animals with one large flagellum and frequently one or more smaller secondary flagella....................*Monadina.*
II. Larger animals, commonly with one large flagellum, mouth and commonly pharynx at the base of the flagellum......*Euglenoidina.*

Sub-Order I. MONADINA.

Colonies, free swimming, yellow to brown; an urn-shaped lorica with an acute posterior end set inside the mouth opening of another individual; 2 chromatophores and an eye-spot and 2 unequal flagella....*Dinobryon.*

Dinobryon

37. *D. setularia* Ehrbg. Plate II, fig. 11.
Kansas: Parsons, August, 1915.

Sub-Order II. EUGLENOIDINA.

Free swimming animalcules, exceedingly flexible in form; spirally marked resistent cuticle; chromatophores green; mouth and pharynx evident, with long flagellum arising from mouth; vacuole at lower end of pharynx with eye-spot close by..........................*Euglena.*

38. *E. viridis* Ehrbg. Plate II, fig. 12.
Kansas: Douglas, August, 1915; Horton, August, 1916, June, 1916; Lyndon, November, 1915; Osawatomie, February, 1917; Council Grove, October, 1916.
Neb. (24); Mo. (11).

CLASS III.

HETEROKONTÆ are characterized by yellow-green chromatophores which are disc shaped, parietal, and lack pyrenoids; motile cells are biciliate with cilia of unequal length; reserve material is oil, not starch.

ORDER I. CONFERVALES.

The only family of this order found in our city water reservoirs is the Confervaceæ, which are unicellular or filamentous. There are usually many disk-shaped chromatophores, and the cells contain one or more nuclei.

Key to the Genera of Confervaceæ.

A. Cells elongate, united into filaments, cell wall thin, breaking up into H sections; asexual reproduction by biciliate zoospores, 1-4 in a cell ....1. *Conferva.*

B. Cells elongate, solitary, rounded at one end and stipitate at the other; straight, arched, or spiral, often attached to water plants ....2. *Ophiocytium.*

1. *Conferva.*

Key to Species.

I. Chromatophores numerous, filaments 6-11 mic. in diam., 2-4 or 6 diam. long ....*C. Minor.*

II. Chromatophores numerous, filaments 6-11 mic. in diam., 2-4 diam. long ....*C. bombycina.*

III. Chromatophores numerous, filaments 6-16 mic. in diam. 1.5-6 diam. long ....*C. utriculosa.*

39. *C. Minor* Klebs.
Kansas: Osage City, November, 1915; Masses, Cherryvale, March, 1916; Washington, April, 1916.

40. *C. bombycina* Agardh.
Kansas: Washington, November, 1915; Burlington, April, 1916; Cherryvale, August, 1915; Chanute, April, 1916; Horton, August, 1915; March, 1916; Neodesha, August, 1915; Mound City, April, 1916.
Colorado (15); Iowa (4).

41. *C. utriculosa.* Plate II, fig. 13.
Kansas: Marysville, August, 1915, November, 1915, April, 1916, August, 1916.
Iowa (4).

2. *Ophiocytium*

42. *O. cochleare* Eichwald.
Kansas: Douglas, August, 1915; Medicine Lodge, August, 1915.

CLASS IV.

CHLOROPHYCEÆ are algæ characterized by true grass-green color; single or united into threads, plates or masses; pyrenoids mostly present; reproduction by zoöspores, akinetes and aplanospores.

Key to Orders of Chlorophyceæ.

Frond of one or more cells.

- * Vegetative cells ciliate and motile, always or except during resting periods, or easily passing into a motile condition. II. *Volvocales.*
- * * Vegetative cells motionless; reproductive cells motile or not.
  - *a.* Reproduction by zygospores formed by the union of 2 non-ciliated gametes..................I. *Conjugales.*
  - *b.* Reproduction by zoospores, not by zygospores.
    - 1. Cells solitary or in a spherical or netlike combination ....III. *Protococcales.*
    - 2. Cells forming simple or branched filaments.
      - * Cells uninucleate, chromatophore usually single, disk-, net-, or star-shaped.....IV. *Ulotrichales.*
      - * * Cells multinucleate, chromatophore net-shaped, as of numerous small disks in a cell. V. *Siphonocladiales.*

ORDER I. CONJUGALES.

Key to Families of Conjugales.

I. Cell wall mostly constricted into symmetrical halves with a differentiated outer layer; solitary or in filaments; cell division follows a fixed type, with interpolation of the younger halves between the old ones ....1. *Desmidiaceæ.*

II. Cells cylindrical, without constrictions, always united in filaments; the new filament always formed directly from the zygospore.

- * The entire protoplasmic contents of the conjugating cells uniting to form the spore...............2. *Zygnemaceæ.*
- * * Only a part of the contents of the conjugating cells used for the spore ....3. *Mesocarpaceæ.*

Family I. DESMIDIACEÆ.

Key to Genera of Desmidiaceæ.

I. Cells not united into filaments, more or less crescentic. 1. *Closterium.*

II. Cells constricted in middle, dumb-bell shaped; end view not angular, margins smooth, dentate or crenate but no spines....2. *Cosmarium.*

1. *Closterium.*

Key to Species.

I. Cells slightly curved; ends not contracted, but tapering, acute with 40-50 mic. length 5-12 times the width; chlorophyll bands, several granules in one row............................*C. lanceolatum.*

II. Cells conspicuously curved, often subsemicircular; width 16-25 mic., cytioderm smooth ....*C. Dianæ.*

43. *C. lanceolatum* Kuetzing.
Kansas: Burlingame, August, 1915; Horton, October, 1916.
Colorado (15); Iowa (4); Nebraska (25).

44. *C. Dianæ* Ehrbg. Plate III, fig. 14.
Kansas: Neodesha, November, 1915; Horton, June, 1916.
Iowa (4); Nebraska (25).

2. *Cosmarium.*

Key to Species.

I. Single chloroplast (with one pyrenoid) in semi-cell.
  A. End view without central inflations, cytioderm punctate, margins granulate, semi-cell semi-obicular, diam. 12-16 mic., *C. leve.*

II. Two chloroplasts (with two pyrenoids) in each semi-cell.
  A. Membrane smooth or lightly punctate. End view with central inflations, margins smooth, sinus acute inwardly, diameter 12-30 mic. ....*C. tithophorum.*
  B. Membrane verrucose, rarely heavy punctate.
    1. End of semi-cells broadly rounded, diam. 60-68 mic. *C. perforatum.*
    2. End of semi-cells truncate, diam. 35-62 mic....*C. Botrytis.*

45. *C. leve* Rabenh.
Kansas: Douglass, 1916.
Iowa (4).

46. *C. tithophorum* Nordst.
Kansas: Douglass, August, 1915.

47. *C. perforatum* Lund.
Kansas: Douglass, August, 1915.

48. *C. Botrytis* (Bory) Menegh. Plate III, fig. 15.
Kansas: Horton, June, 1916, October, 1916; Parsons, August, 1915; Jewell City, 1915; Lyndon, November, 1915; Coffeyville, July, 1916; Burlingame, October, 1916.
Colorado (15); Iowa (4); Nebraska (25); Missouri (11).

Family II. ZYGNEMACEÆ.

Key to the genera of Zygnemaceæ.

I. Chromatophores one or two, star-shaped..............1. *Zygnema.*
II. Chromatophores one or more, parietal, more or less spiral. 2. *Spirogyra.*

1. *Zygnema.*

49. *Z.* ——— *sp.?*
Kansas: Horton, June, 1916.

2. *Spirogyra.*

Key to Species.

I. Septa between cells smooth, not folded back or replicate.
  A. Fruiting cells little or not at all swollen.
    1. One chromatophore in each cell.
      a. Zygospore broad ovoid, 1.5-2.5 times as long as wide, diam. 18-20 mic..........................*S longata.*
      b. Zygospore ellipsoid, 2-3 times as long as wide, diam. 19-23 mic. ....*S. communis.*
    2. Two or more chromatophores in each cell.
      a. Zygospore ovoid or globose, vegetative filaments 33-40 mic. in diam., cells 2-4 times as long as wide. *S. decimina.*
      b. Zygospore compressed ovoid, 140-160 mic. in diam., vegetative filaments, 150-160 mic. in diam.........*S. crassa.*
  B. Fruiting cells distinctly swollen, one chromatophore in each cell, end walls replicate, filaments 24-33 mic. in diam., zygospore ellipsoid, 40-48 mic. in diam......................*S. quadrata.*

50. *S. longata* Kuetz. Plate III, fig. 16.
Kansas: Coffeyville, October, 1916.
Iowa (4); Colorado (15); Mo. (11).

51. *S communis* Kuetz.
Kansas: Horton, June, 1916.
Iowa (4).

52. *S. decimina* Kuetz.
Kansas: Horton, June, 1916, masses.
Iowa (4); Nebraska (24).

53. *S. crassa* Kuetz.
Kansas: Gardner, June, 1916, great masses.
Iowa (4); Colorado (15); Nebraska (25).

54. *S. fluviatilis* Hilse.
Kansas: Paola, November, 1915; July, 1916; masses.
Iowa (4); Nebraska (24).

55. *S. quadrata* (Hass) Petit.
Kansas: Burlingame, October, 1916.
Iowa (4); Nebraska (24).

Family III. MESOCARPACEÆ.

Chromatophore an axillary plate with two or more pyrenoids. *Mougeotia.*

56. *M. elegantula* Whittrock.
Kansas: Pittsburg, September, 1915.

57. *M. delicatula* Wolle.
Kansas: Douglass; November, 1915; April, 1916; June, 1916.

58. *M.* ——— *sp.?*
Kansas: Horton, June, 1916, mixed with Spirogyra and Zygnema.

59. *M.* ——— *sp.?*
Kansas: Chanute, August, 1916, only a few strands.

ORDER II. VOLVOCALES.

Key to Families of Volvocales.

1. Cells free, never forming colonies........1. *Chlamydomonadaceæ.*
II. Cells united in colonies.
  * Colonies of various form, cells motile when free, sometimes when in colonies.....................3. *Tetrasporaceæ.*
  * * Colonies spherical, ovoid, or disk-shaped; vegetative cells normally always motile..................2. *Volvocaceæ.*

Family I. CHLAMYDOMONADACEÆ.

Key to genera of Chlamydomonadaceæ.

I. Cells spherical or ovoid.
  * Protoplasmic threads passing through the cell wall. 1. *Hæmatococcus.*
  * * No protoplasmic threads in cell wall........2. *Chlamydomonas.*

1. *Hæmatococcus*

60. *H. pluvialis* Flotow. (*H. lacustric* Girod).
Kansas: Osawatomie, August, 1915.
Nebraska (2); Colo. (15).

2. *Chlamydomonas.*

61. *C. communis* Snow. Plate III, fig. 17.
Kansas: Augusta, August, 1915; Fredonia, August, 1915.
Kansas: Jewell City, August, 1915; Chanute, November, 1915; Osawatomie, November, 1915; Cherryvale, October, 1916; Burlington, April, 1916; Lyndon, March, 1916.

Family II. VOLVOCACEÆ.

1. *Pandorina.*
Colony globose, of 16-32-64 rotund cells; cells surrounded by a firm membrane.

62. *P. Morum* (Müll) Bory. Plate III, fig. 18.
Kansas: Burlington, April, 1916; November, 1915; Lyndon, March, 1916; Emporia, August, 1916; Parsons, October, 1916; Garnett, August, 1916; Paola, November, 1915; Osawatomie, October, 1916.
Iowa (4); Missouri (11).

Family III. TETRASPORACEÆ.

Key to genera of Tetrasporaceæ.

I. Cells and colony with some definite form and arrangement.
* Cells radiately arranged in botryoidal mass. 1. *Botryococcus.*
* * Cells not radiately arranged, without stalks, scattered more or less in twos and fours, mature frond an expanded delicate membrane ....2. *Tetraspora.*

1. *Botryococcus.*

63. *B. Braunii* Kuetz. Plate III, fig. 19.
Kansas: Gardner, June, 1916.

2. *Tetraspora.*

Key to Species.

I. Frond an irregularly inflated sac.
A. Almost colorless, cells spherical, by twos, variable in size, 3-12 mic. in diam.................................*T. gelatinosa.*
B. Green, cells elliptic, angular, unusually small and by twos, 5-7 mic. in diam.................................*T. explanata.*
II. Frond at first tubular, but soon splitting into irregular segments, often much perforate, of a yellowish color; cells 7-11 mic. in diam., generally in fours.................................*T. lubrica.*

64. *T. gelatinosa* (Vauch) Desv.
Kansas: Council Grove, March, 1916.
Colo. (15); Iowa (4); Mo. (11).

65. *T. explanata* Kuetz.
Kansas: Emporia, March, 1916.

66. *T. lubrica* (Roth).
Kansas: Lansing, October, 1916.
Colorado (15); Iowa (4); Neb. (25).

ORDER III. PROTOCOCCALES.

Key to the Families of Protococcales.

I. Cells united in regular, net- or disk-shaped colonies, not gelatinous III. *Hydrodictyaceæ.*

II. Cells free or united in gelatinous colonies, uninucleate, of definite form, with single chromatophore.

* Cells dividing vegetatively............II. *Scendesmaceæ.*

* * Vegetative cell-division rare and abnormal.
I. *Protococcaceæ.*

Family I. PROTOCOCCACEÆ.

1. *Characium.*
Cells solitary, often distinctly stipitate.

Key to the Species of Characium.

I. Sessile upon plants, cells 7-9 mic. in diam..............*C. sessile.*

II. Cells erect, at first lanceolate, later ellipsoid, obtuse, 20-42 by 7-18 mic., stipe slender about 4 mic. long.................*C. Nægelii.*

67. *C. sessile* Hermann.
Kansas: Horton, June, 1916.

68. *C. Nægelii* A. Braun. Plate III, fig. 20.
Kansas: Leavenworth, July, 1916.
Iowa (4); Nebraska (24).

Family II. SCENEDESMACEÆ.

Key to genera of Scenedesmaceæ.

A. Plants not living in cell of animals; no external gelatinous **thallus.**

* Mature cell solitary, mother cell elongate, acinular or fusiform, dividing by oblique walls into daughter cells.
1. *Rhaphidium.*

* * Mature cells united in colonies.

a. Cells elongate, side by side in a single or double series.
2. *Scenedesmus.*

b. Cells without spinous projections, symmetrically arranged about a center, united to the center by gelatinous strands.
Strands unbranched, short............3. *Cœlastrum.*
Strands unbranched, spherical cells at end.
4. *Dictyosphærium.*

1. *Rhaphidium* (*Ankistrodesmus*).

Key to Species.

I. Cells 12-25 diam. long, ends very acute.............*R. falcatum.*

II. Cells 3-12 diam. long, ends apiculate, cells variously twisted and curved ....*R. convolutum.*

69. *R. falcatum* (Corda) Cooke. (*R. polymorphum* Wolle, *Ankistrodesmus falcatus* (Corda) Ralfs.)
Kansas: Paola, March, 1916; November, 1915; Chanute, November, 1915; Leavenworth, November, 1915; Ottawa, November, 1915.
Iowa (4); Missouri (11); Colorado (15); Nebraska (25).

70. *R. polymorphum* var. *contortum.* (Thur.) Wolle (*A. falcatus* var. *spiralis* (Thur.) West.)
Kansas: Lyndon, March, 1916; November, 1915; October, 1916.
Missouri (11).

71. *R. polymorphum.* var. *sigmoideum* Rab. Plate III, fig. 22.
Kansas: Burlington, April, 1916; Independence, March, 1916, December, 1915; Lyndon, March, 1916; Jewell City, October, 1916.
Nebraska (24).

72. *R. convolutum* (Corda) Rab. (*A. convolutus* Corda). Plate III, fig. 21.
Kansas: Douglas, August, 1915; Cherryvale, December, 1915; Coffeyville, November, 1915.
Iowa (4); Nebraska (24).

2. *Scenedesmus.*

Key to Species.

I. Ends of cells acute, colonies of 4-8 cells, 5-27 by 3-9 mic. *S. obliquus.*

II. Ends of cells rounded, terminal cells of series with long projections, colonies of 2-8 cells, arranged in a single series or in two alternating rows .... *S. quadricauda.*

73. *S. obliquus* (Turp) Kuetz. (*S. acutus* Nägeli). Plate III, fig. 24.
Kansas: Leavenworth, July, 1916.
Iowa (4); Nebraska (24); Missouri (11); Colorado (15).

74. *S. obliquus* var. *dimorphus* (Turp) Hansgirg.
Kansas: Lyndon, November, 1915, October, 1916; Paola, July, 1916.
Colorado (15); Iowa (4); Nebraska (24); Missouri (11).

75. *S. quadricauda* (Turp) Brebisson; (*S. caudatus*) Wolle.
Kansas: Atchison, August, 1915; Douglas, August, 1915; Waconda Springs, July, 1916; Garnett, August, 1916; Cherryvale, October, 1916.
Iowa (4); Missouri (11-9).

76. *S. quadricauda* var. *typicus* Kirchner. Plate III, fig. 23.
Kansas: Osawatomie, August, 1915.
Nebraska (24); Colorado (15).

3. *Coelastrum.*

Key to Species.

I. Cells united by quite short processes, interspaces much smaller than diam. of cell.
  A. Cells 5-12 mic. in diam. and somewhat lobed with truncate projection at the middle.......................... *C. cambricum.*
  B. Cells 6-16 mic. in diam., spherical and united by the gelatinous surfaces .... *C. microporum.*

77. *C. cambricum* Archer.
Kansas: Washington, August, 1916, July, 1916.

78. *C. microporum* Nägeli.
Kansas: Douglas, August, 1915.
Missouri (11).

4. *Dictyosphærium.*

79. *D. Ehrenbergianum* Nägeli. Plate III, fig. 25.
Kansas: Parsons, August, 1915, December, 1915; Paola, August, 1915; Lyndon, November, 1915; Coffeyville, July, 1916.
Missouri (11).

Family III. HYDRODICTYACEÆ.

The only genus of the Hydrodictyaceæ found was Pediastrum.

Key to Species.

I. Lobes of marginal cell simple, disk perforate............ *P. duplex.*

II. Lobes of marginal cell imarginate, bidentate or bifid, disc continuous .... *P. tetras.*

80. *P. duplex* Meyen; (*P. pertusum*) Wolle. Plate III, fig. 26.
Kansas: Douglas, August, 1915; Mound City, August, 1915; Yates Center, August, 1915; Coffeyville, July, 1916.
Missouri (11); Colorado (15).

81. *P tetras* (Ehrbg.) Rolfs; (*P. Ehrenbergii*) A. Braun.
Kansas: Burlingame, October, 1916.
Iowa (4); Missouri (11); Colorado (15).

ORDER IV. *ULOTRICHALES.*

Key to the Families of Ulotrichales.

I. Chromatophore net-, disk-, or band-shaped.
  A. Fronds unbranched filaments; sexual reproduction by isogamous gametes .... *Ulotrichaceæ.*
  B. Fronds branched or simple.
    * Sexual reproduction by oogonia and antheridia; chromatophores net-shaped; filaments erect..........*Œdogoniaceæ.*
    * * Sexual reproduction by isogamous zoögametes; fronds filamentous usually with hairs ....*Chætophoraceæ.*

Family I. ULTRICHACEÆ.

Key to the genera of Ulotrichaceæ.

A. Filaments monosiphonous throughout, cells forming a cylindrical filament.
  * Cells without pyrenoid, chromatophore a granular sheath covering the wall more or less completely.....1. *Microspora.*
  * * Cells with one or more pyrenoids, chromatophore a zonate band sometimes incomplete...................2. *Ulothrix.*

1. *Microspora.*

82. *M. stagnorum* Kuetz. Lagerheim.
Kansas: Olathe, August, 1915, November, 1915, April, 1916, in masses along with *Microthamium Kuetzingianum*, July, 1916.
Iowa (4). Missouri (11).

2. *Ulothrix.*

83. *U. tenerrima* Kuetz.
Kansas: Washington, April, 1916, mixed with *Conferva minor.*
Iowa (4); Colorado (15); Nebraska (3).

Family II. ŒDOGONIACEÆ.

Œdogonium was the only genus of the Œdogoniaceæ found.

84. *Oe. irregulare* Wittrock. Plate IV, fig. 30.
Kansas: Douglass, June, 1916, great fruiting masses.

85. *Oe.* ———*sp.?*
Kansas: Leavenworth, July, 1916.

86. *Oe.* ———*sp.?*
Kansas: Jewell City, November, 1915, August, 1915, October, 1916.

87. *Oe.* ———*sp.?*
Kansas: Medicine Lodge, August, 1915.

Family III. CHÆTOPHORACEÆ.

Key to the genera of Chætophoraceæ.

A. Fronds erect with differentiated base and apex.
  * Fronds less than 1 mm. high, tips not acute nor setiferous 1. *Microthamnion.*
  * * Fronds larger, tips generally acute or setiferous, filaments practically free.
    a. Fascicled ramuli different in character from stem. 2. *Draparnaldia.*
    b. Stem, branches, and ramuli little differentiated 3. *Stigeoclonium.*

1. *Microthamnion.*

88. *M. Kuetzingianum* Nägeli.
Kansas: Olathe, April, 1916.
Nebraska (3); Missouri (11).

2. *Draparnaldia.*

89. *D. glomerata* (Vauch) Agardh. Plate IV, fig. 27.
Kansas: Neodesha, November, 1915.
Nebraska (25); Colorado (15).

3. *Stigeoclonium.*

Key to Species.

I. Opposite branching predominant; filaments 11-30 mic. in diam; lower cells usually longer than broad; ramuli sharp-pointed *S. lubricum.*

II. Alternate branching predominate, filaments short, tufted, 7-9 mic. in diam., ramuli scattered, tips setiferous............*S. æstivale.*

90. *S. lubricum* (Dilliv.) Kuetz.
Kansas: Atchison, November, 1915.
Missouri (11).

91. *S. æstivale* Hazen. Plate IV, fig. 28.
Kansas: Galena, December, 1915, April, 1916.
Missouri (11).

ORDER V. SIPHONOCLADIALES.

The only family of the Siphonocladiales in the reservoirs was the Cladophoraceæ of which Cladophora was the only genus found.

1. *Cladophora.*

Key to Species.

I. Fronds permanently attacked to substratum.
  A. Ramuli in dense terminal clusters straight or slightly curved.
    1. Lower branching mostly dichotomous; branches connate for some distance; main filaments 85-120 mic. in diam. *C. canalicularis.*
    2. Branching mostly alternate; branches not connate, 75-100 mic. in diam ....*C. glomerata.*
  B. Ramuli not in dense terminal clusters.
    1. Frond not over 1 cm. high; filaments about 40 mic. in diam. *C. uberrima.*
    2. Frond larger, 10-40 cm. high; filaments 75-125 mic. in diam. *C. callicoma.*

92. *C. canalicularis* (Roth) Kuetz.
Kansas: Independence, December, 1915.
Nebraska (24); Missouri (11).

93. *C. glomerata* Kuetz. Plate IV, fig. 29.
Kansas: Mound City, August, 1915.
Missouri (9); Colorado (15); Nebraska (24-25); Iowa (4).

94. *C. Uberrima* Lambert.
Kansas: Burlingame, November, 1915, October, 1916.

95. *C. callicoma* Kuetzing.
Kansas: Horton, June, 1916.

96. *C.———sp.?*
Kansas: Council Grove, November, 1915.

97. *C———sp.?*
Kansas: Medicine Lodge, August, 1915.

CLASS V.

BACILLARIEÆ or Diatoms include a very large number of unicellular plants. They have beautifully marked siliceous cell-walls, the marks being constant in size and arrangement for each species; cell constructed in two parts (*valves*) one overlapping the other in the manner of a pill box; a longitudinal cleft (*raphe*) which runs from end to end is a series of openings through which pseudopodia are thrust for locomotion. The cells contain a central nucleus swung in cytoplasm and two or more brown-greenish-yellow chromoplasts. "In cell division the growth of the protoplast separates the valves and division occurring in the plane of the valves, each new protoplast possesses one of the old valves and forms a new valve on the naked side." (8*a*) It has been estimated that there are over ten thousand species of Diatoms.

Key to the Subfamilies of Bacillarieæ.

I. Valves with a concentric or radiating structure around a central point; without raphe; valve view circular or broadly elliptical. *Centricæ.*

II. Valves never concentric, mostly broad-shaped, with a raphe. *Pennatæ.*

Subfamily I. CENTRICEÆ.

The Discoideæ is the only tribe of the Centricæ which has representatives in our Kansas reservoirs, Melosira being the genus identified. Melosira is characterized by frustules with circular, very wide connective bands, attached valve to valve forming long cylindrical filaments.

98. *Melosira* Agardh. Plate IV, fig. 31.
Kansas: Burlington, April, 1916; Emporia, April, 1916; Horton, June, 1916.
Nebraska (25-2); Iowa (4).

Subfamily II. PENNATÆ.

Key to the Tribes of Pennatæ.

I. Cells mostly straight, rod shaped or lanceolate, without a raphe but sometimes with pseudoraphe .... *Fragilarioideæ.*

II. Cells crooked or suddenly bent, with a raphe on one valve and a pseudoraphe on the other........................ *Achnanthoideæ.*

III. Cells with a raphe on each valve.................... *Naviculoideæ.*

IV. Cells with the raphe concealed in submarginal wings of each valve. *Surirelloideæ.*

Tribe I. *Fragilarioideæ.*

Key to the genera of Fragilarioideæ.

I. Frustules elongated, straight or slightly curved, united at base in fan-shaped clusters; usually straight with almost parallel sides, transversely striated and mostly with pseudoraphe........*Synedra.*

II. Frustules attached side by side into a ribbon; valves elongated with lanceolate ends; frustules in girdle view rectangular and in contact with each other entire length........................*Fragilaria.*

99. *Synedra* Ehrbg. Plate IV, fig. 38.
Kansas: Widely distributed, found over twenty times.
Nebraska (2-3-24-25); Iowa (4).

100. *Fragilaria* Lyngby. Plate IV, fig. 33.
Kansas: Douglass, August, 1915; Independence, April, 1916; Horton, June, 1916; Paola, July, 1916.
Nebraska (1-2-24-25); Iowa (4).

Tribe II. *Achnanthoideæ.*

Cocconeis, the only genus of the Achnanthoideæ thus far identified; frustules of the valves unlike; valves broadly oval.

101. *Cocconeis* Ehrbg. Plate IV, fig 37.
Kansas: This genus was found at Cedarvale in August, 1916.
Nebraska (2-24-25); Iowa (4).

Tribe III. *Naviculoideæ.*

Key to the genera of Naviculoideæ.

I. Frustules symmetrical, valves boat-shaped; marked with transverse furrows having a slight radial tendency; some long and narrow and some short and wide; ends either pointed or rounded. *Navicula.*

II. Very similar to Navicula, frustules rectangular in girdle view. A narrow clear space along the raphe and a wider transverse clear space at the medial nodule extending to the sides of the valve gives the valves a marking having the appearance of a cross. ***Stauroneis.***

III. Frustules much the same as Navicula, but with axis turned like a letter S. Raphe sigmoidal ....*Pleurosigma.*

IV. Frustules borne on pedicels more or less branched. Valves bilaterally symmetrical, wedge shaped with central nodule near the large end ....*Gomphonema.*

V. Frustules elongated symmetrical with respect to the minor axis. Valves with one side very convex and the other side hardly at all convex, surface transversely striated..................*Cymbella.*

VI. Frustules, when young, enclosed in a mucilaginous tube, in which they multiply by division; valves more or less cymbiform; a straight raphe divides the valves into two unequal parts. *Encyconema.*

VII. Frustules ovoidal to rectangular in girdle view. Valves extremely unsymmetrical with a convex and concave side, an eccentric raphe, etc. The transverse striæ radiate somewhat from the median nodule ....*Amphora.*

VIII. Frustules free, elongated, valves linear, pointed; surface punctate or transversely striate............................*Nitzschia.*

102. *Navicula.* Bory. Plate IV, fig. 36.
Kansas: Very widely distributed, having been found eighty-five times.
Nebraska (1-2-3-24-25); Iowa (4).

103. *Stauroneis* Ehrbg.
Kansas: Cedarvale, August, 1916.
Nebraska (1-2-3-24-25); Iowa (4).

104. *Pleurosigma* W. Smith. Plate IV, fig. 35.
Kansas: Found eleven different times during the survey.
Nebraska (1-2-3-24-25); Iowa (4).

105. *Gomphonema* Agardh.
Kansas: Cherryvale, 1915; Mound City, August, 1915; Medicine Lodge, August, 1915; Burlingame, November, 1915, October, 1916; Jewell City, November, 1915; Horton, June, 1916.
Nebraska (1-2-3-24-25); Iowa (4).

106. *Cymbella* Agardh. Plate IV, fig. 34.
Kansas: Rather generally distributed. Identified about 25 times.
Nebraska (1-2-3-24).

107. *Encyonema* Agardh. Plate IV, fig. 32.
Kansas: Waconda Springs, July, 1916; clinging together in gelatinous masses extending into filaments.
Nebraska (2).

108. *Amphora* Ehrbg.
Kansas: Identified ten different times.
Nebraska (1-2-24); Iowa (4).

109. *Nitzschia* Hassall.
Kansas: Chanute, November, 1915; Cherryvale, November, 1915; Independence, December, 1915; April, 1916; Ottawa, November, 1915; Burlington, April, 1916; Council Grove, April, 1916; Horton, April, 1916.
Nebraska (1-2-3-24-25); Iowa (4).

Tribe IV. *Surirelloideæ.*

110. *Surirella* (Turpin).
Oval valves with conspicuous transverse tubular striæ between which are sometimes very pearled striæ; wide pseudoraphe.
This genus was found only three times, *i. e.*, Kansas: Chanute, November, 1915; Council Grove, April, 1916; Emporia, April, 1916.
Nebraska (24): Iowa (4).

Table III.—Seasonal Distribution and Frequency of the Genera of Algæ.

Genus	Summer 1915	Winter 1915	Spring 1916	Summer 1916	Winter 1916	Total
Myxophyceæ						
Anabaena			1	3		4
Clathrocystis	1	2	4	1		8
Gleocapsa				1		1
Hypheothrix			1			1
Lyngbya	6	8	10	9	9	42
Merismopedium	1	1	1	1	2	6
Microcoleus	1	1				2
Nostoc		1		1		2
Oscillatoria	30	17	21	10	13	91
Phormidium		1		1		2
Spirulina	3	1		1	3	8
Total						167
Flagellata						
Dinobryon	1					1
Euglena	1	1		2	1	5
Total						6
Heterokontæ						
Conferva	4	3	7	1		15
Ophiocytium	2					2
Total						17
Chlorophyceæ						
Botryococcus			1			1
Characium				2		2
Chlamydomonas	3	2	2		1	8
Cladophora	2	3		1	1	7
Closterium	1	1		1	1	4
Coelastrum	1			2		3
Cosmarium	4	1	1	2	3	11
Dictyosphaerium	2	2	1			5
Draparnaldia		1				1
Microspora	1	1	1	1		4
Microthamium			1			1
Mougeotia	1	1	1	3		6
Oedogonium	2	1		2	1	6
Pandorina		2	2	2	2	8
Pediastrum	3		1		1	5
Raphidium	1	8	5		3	17
Scenedesmus	3	1	1	3	2	10
Spirogyra		1	1	3	2	7
Stigeoclonium		2	1			3
Tetraspora			2		1	3
Haematococcus	1					1
Ulothrix			1			1
Zygnema				1		1
Total						114
Bacillarieæ						
Amphora			1	2	7	10
Cymbella	2	8	7	5	1	23
Cocconeis				1		1
Encyonema			1			1
Fragillaria	1		1	2		4
Gomphonema	3	2		1	1	7
Melosira			1	1	1	3
Navicula	19	20	23	14	9	85
Nitzschia		3	4		1	8
Pleurosigma	3	3	2		3	11
Stauroneis				1		1
Surirella		1	2			3
Synedra	5	5	10	2	3	25
Total						182
No. of Genera	29	31	32	32	24	
Total of Frequency						486

Table III shows the seasonal distribution and frequency of the various genera of algæ. Although there were but thirteen genera of diatoms classified, they appeared 182 times, while the twenty-three genera of Chlorophyceæ were found only 114 times. Eleven genera of Myxophyceæ were found 167 times. The grand total indicates that the fifty-one genera of algæ appeared 486 times throughout the survey. It is of interest to note that, although the specific genera varied from season to season, the number of genera remained quite constant. During the period of my observations the season of the year did not seem to have any such relation to the species found, as Transeau (21*a*) discovered in his study of algæ of the pools and ponds of central Illinois. This may be due to the artificial conditions brought about by the chemical treatment and dredging of the reservoirs. The length of time necessary to establish such periodicity in artificial conditions might be greater than in natural conditions where observations were carried on for seven and a half years.

Of the many cases handled by the workers in the water laboratory, the following instances show the value of the copper-sulfate method of removing algæ from the reservoirs in Kansas.

In June, 1916, the water at Horton, Kan., was in bad condition, according to Supt. W. W. Wood. The author made a trip to Horton and found the water had a disagreeable odor and a dark, reddish-brown color. This color could not have been due to iron, since laboratory diagnosis had shown no iron present. The reservoir was found to be covered with a decaying mat of Cladophora, Spirogyra, Zygnema, Mougeotia, Anabæna, Closterium, Euglena and Characium. The odor of the water in the reservoir, as well as the color, was due to these decaying forms. The settling basin showed a count of sixty-eight organisms per cubic centimeter of water, forty-nine of which were Anabæna. The basin, with a capacity of 600,000 gallons of water, was treated with two and one-half pounds of $CuSO_4$ and allowed to stand for twenty-four hours. The supply of the basin was changed from the infested reservoir to the creek, whose overflow supplies the reservoir and whose waters at that time were comparatively free from algæ. In forty-eight hours all odors and color had disappeared from the water in the basin.

In the fall of 1916, the Olathe water system was infested with heavy growths of Conferva. Much of the dense entanglement was raked out upon the banks and the water was treated at the rate of six pounds of copper sulfate to a million gallons of water. The water was usable within three days.

Russell, whose impounding reservoir has a capacity of 39,000,000 gallons, was troubled in September, 1916, with heavy growths of Anabæna, Conferva and Cladophora. The lowering waters had left a carpet of decaying algæ about the edge. The reservoir was treated with 50 pounds of copper sulfate distributed from a sack at the stern of a boat, the banks were sprayed with about 100 pounds of the $CuSO_4$ in solution. No further trouble was reported.

In March, 1917, Burlington reported a bad taste to the city water and offensive odors rising especially from the filter beds. Analyses showed the filters to be covered with numerous Synedra, Navicula, Chlamydomonas and Clathrocystis. The filters were washed, and about a foot of water, to which one pound of $CuSO_4$ had been added, was left standing in each. The basins were treated with eight pounds to the million gallons. The filters, after standing for eight hours, were drained into the sewer, and the water now let in from the basin and filtered was in good condition.

Occasionally difficulty which seems to be due to the algæ may be caused by the growth of small animals. A few cases in our state where water from the basins and filters has given off foul odors have been traced to this cause. For example, Lyndon, in May, 1917, and Kansas City, in January, 1917, reported offensive, fishy odors coming from their settling basins and filters, and that the walls were covered with a brownish-gray growth resembling masses of roots. Samples of this material analyzed in the laboratory proved to be Polyzoa, minute animals forming mosslike clusters. These small animals when in a state of decomposition give off an odor much the same as comes from a stagnant fish pond. By a purely mechanical treatment, consisting in scraping the walls and carefully cleaning the filters, the difficulty as to odors was removed. On the other hand, the State Hospital at Osawatomie, in February, 1917, when troubled by a protozoan, Vorticella, in the water supply, eradicated it by the use of copper sulfate.

Other similar cases of the successful use of copper sulfate in the water reservoirs have been recorded by the workers in the Kansas water laboratory. The method has been practically the same in all cases and the dosage and identification of the organisms have been easily made from tables and keys such as given in this report.

SUMMARY.

1. Out of the one hundred and ten species of algæ listed in this paper only twelve have been reported previously in this state; thirty-seven have not been reported in our neighboring states. Fifty-five species of the Chlorophyceæ were identified, thirty-six of the Myxophyceæ, thirteen Bacillariæ, four Hetreokontæ and two Flagellata. Fourteen species of Oscillatoria were classified. This genus was found ninety-one times and is the most common algal form prevalent in our reservoirs. The diatoms were always present, Navicula being found eighty-five times.
2. The algæ of our state which have been found to be the most active in causing bad tastes, odors or colors in our drinking water are Anabæna, Conferva, Oscillatoria, Spirogyra, Cladophora, Clathrocystis, Synedra and Navicula. Animals of the Polyozoan and Protozoan groups have also been found to cause these difficulties.
3. The collections of algæ during the five seasons brought out no changes due to the differences in the seasons. To determine whether this is due to the absence of seasonal influence on the flora or to the artificial conditions of the reservoirs requires data from a longer period of time than is covered by this paper.
4. The copper sulphate treatment for algal trouble has been used successfully in Kansas.

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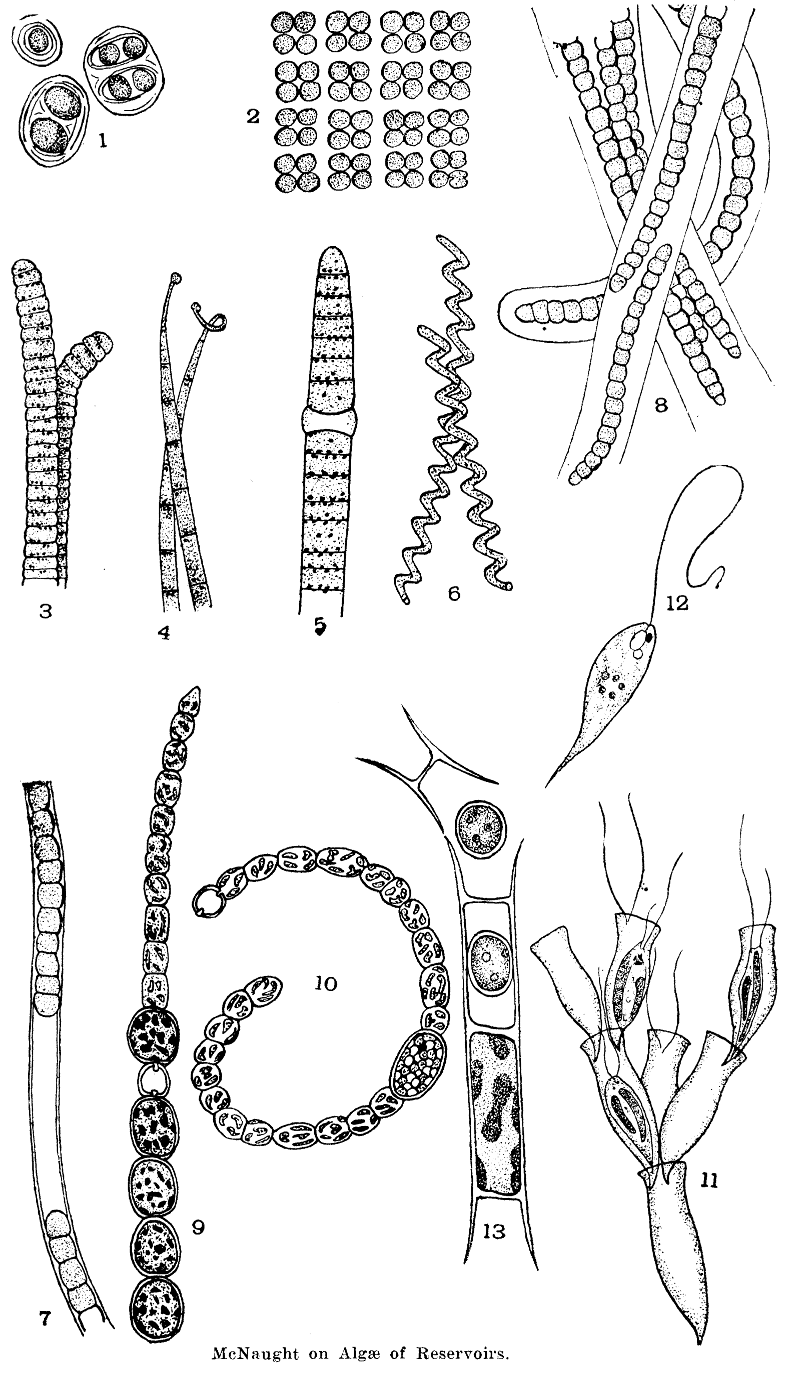
These drawings were made by the aid of the camera lucida.

PLATE II.

Fig. 1.	Gleocapsa arenaria	× 750
Fig. 2.	Merismopedium glaucum	× 520
Fig. 3.	Oscilliatoria tenuis	× 750
Fig. 4.	Oscilliatoria amphibia	× 750
Fig. 5.	Oscilliatoria brevis	×1000
Fig. 6.	Spirulina major	× 750
Fig. 7.	Lyngbya putealis	× 400
Fig. 8.	Hypheothrix coriaceæ	×2200
Fig. 9.	Anabæna variabilis	× 750
Fig. 10.	Anabæna flos-aquæ	× 750
Fig. 11.	Dinobryon setularia	× 750
Fig. 12.	Euglena viridis	×1500
Fig. 13.	Conferva utriculosa	× 600

PLATE II.

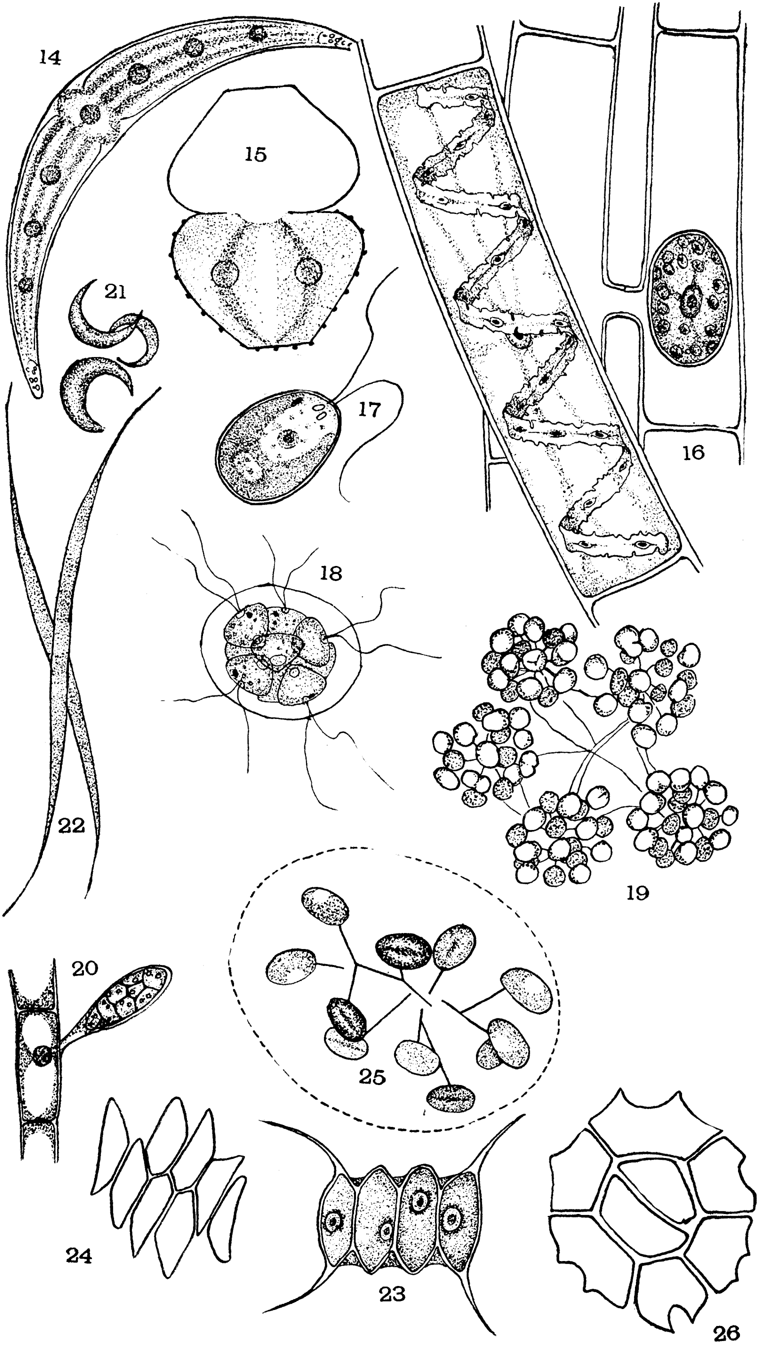


McNaught on Algæ of Reservoirs.

PLATE III.

Fig. 14.	Closterium Dianæ	× 800
Fig. 15.	Cosmarium Botrytis	× 520
Fig. 16.	Spirogyra longata	× 520
Fig. 17.	Chlamydomonas communis	×1500
Fig. 18.	Pandorina Morum	× 300
Fig. 19.	Botryococcus Braunii	× 450
Fig. 20.	Characium Nægelii	×
Fig. 21.	Rhaphidium convolutum	× 750
Fig. 22.	Rhaphidium polymorphum var. sigmoideum	× 520
Fig. 23.	Scenedesmus quadricauda var. typicus	×1200
Fig. 24.	Scenedesmus obliquus	×1200
Fig. 25.	Dictyosphærium Ehrenbergianum	×1200
Fig. 26.	Pediastrum duplex	

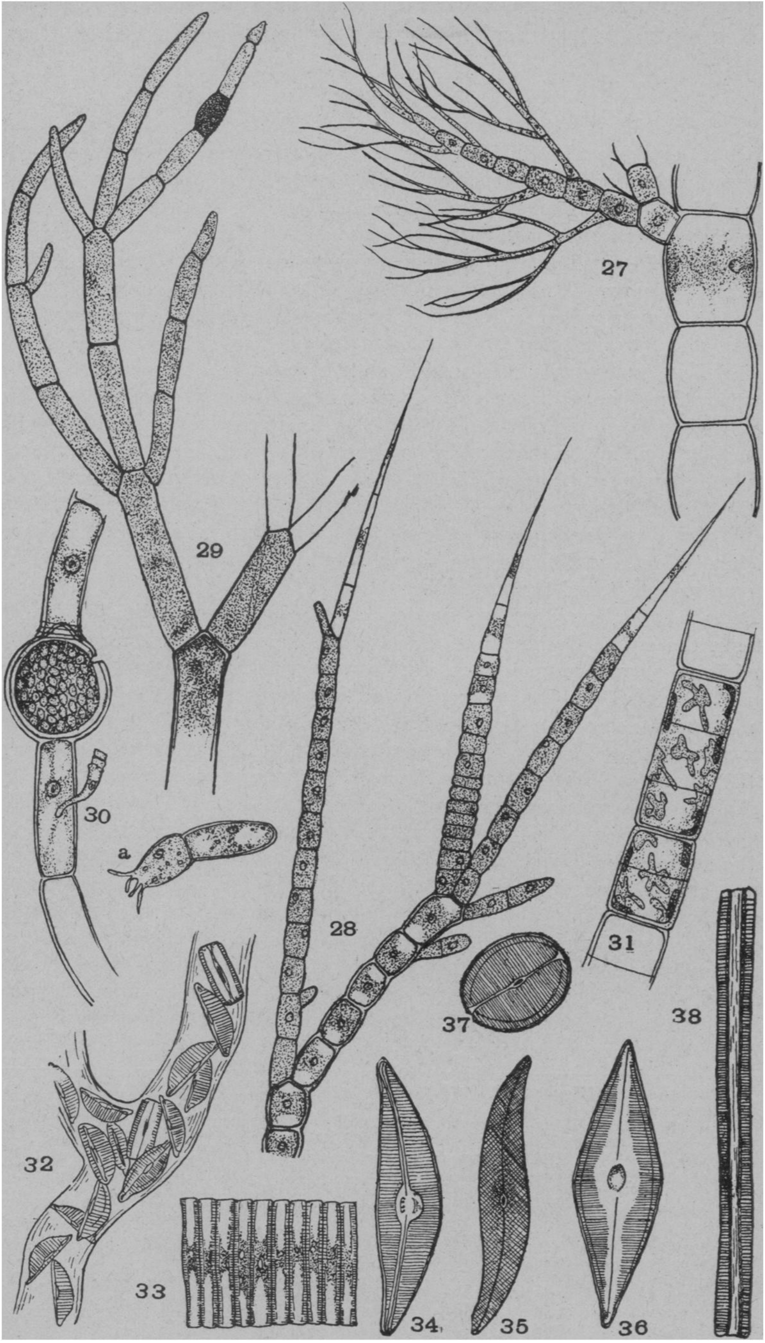
TRANS. KANSAS ACAD. SCI., VOL. XXIX. PLATE III.



McNaught on Algæ of Reservoirs.

PLATE IV.

Fig. 27.	Draparnaldia glomerata	× 520
Fig. 28.	Stigeoclonium æstivale	× 520
Fig. 29.	Cladophora glomerata	× 375
Fig. 30.	Œdogonium irregulare	× 300
Fig. 30*a*.	Œdogonium, small plant	× 300
Fig. 31.	Melosira	× 500
Fig. 32.	Encyonema	× 600
Fig. 33.	Fragilaria	× 500
Fig. 34.	Cymbella	× 400
Fig. 35.	Pleurosigma	×
Fig. 36.	Navicula	×
Fig. 37.	Cocconeis	×
Fig. 38.	Synedra	×



McNaught on Algæ of Reservoirs.